

# Fuzzy Controlled Shunt Active Power Filter for Line Harmonic Mitigation

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**Abstract-** Epidemic applications of power electronic based non-linear loads result in increase of harmonics in the power system. The current harmonics produced by these non-linear loads result in voltage distortion and leads to various power quality problems. So it is important to eliminate the harmonics in the power system. The harmonic elimination through Shunt Active Power filter (SAPF) provides higher efficiency and more pliable when compared with passive filters. This paper presents a standard surrogate and efficacious method for controlling SAPF. The shunt active power filter is controlled by Fuzzy Logic Controller(FLC) which is proficient of reducing the THD in power system is proposed. A simulation has been accomplished in MATLAB/SIMULINK and an attempt is made to reduce the THD levels of source current below the IEEE-519-1992 recommended practice. This proposed method provides reduced THD as per the standard and the voltage of dc-link capacitor is settled within two cycles and better system response is obtained.

**Index Terms** - Power Quality, SAPF, PI Control Algorithm, Fuzzy Control Algorithm.

## I. INTRODUCTION

An ample penetration of non linear loads in distribution side is an area that is receiving a great deal of attention recently. Especially the current harmonics injected by these loads causes voltage distortions, overheating of the devices, low power factor and low system efficiency [1]. In order to overwhelm these issues active power filters are used particularly Shunt Active Power Filters (SAPF) based on current controlled PWM converters have been perceived as a doable solution. Duke and Round [2] have proposed a work in which by sensing the load current, the stipulated compensating current is determined using a simple pretentious sinusoid generation technique. This is further customized by sensing line currents alone, which is simple and easy to implement. The reference current was generated using conventional PI controller. The decisive linear mathematical models are needed for the PI controller which is arduous to attain and fails to produce assuasive results under load disturbances, and parameters varying conditions.

Anew, Fuzzy Logic Controllers (FLCs) have reaped a great interest in certain applications. The advantages over conventional PI controllers are that they do not require precise mathematical model, able to handle non-linearity and robust. This paper focuses a fuzzy logic controlled approach for shunt

active power filter for harmonic and reactive power compensation. They offer an efficient control method under certain load and supply conditions and also endeavor much better response.

## II. BASIC PRINCIPLE OF SAPF

A shunt APF consists of either controllable voltage source or current source. The most common method which is used today is Voltage Source Inverter (VSI) based shunt APF. "Fig.1" shows the configuration of VSI based shunt APF. This will act as a current source and inject the equal amount of harmonic current  $i_c$  present in source current, but in opposite magnitude [3]. Thus the original harmonic current present in the source current gets eliminated and the sinusoidal waveform of source current is retrieved.

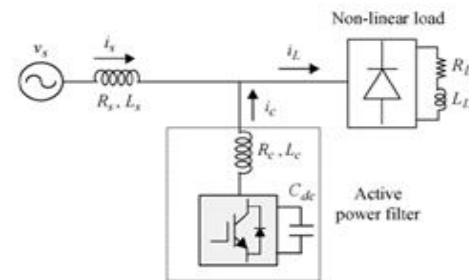


Figure 1. Configuration of VSI based shunt APF

## III. REFERENCE CURRENT ESTIMATION USING PI ALGORITHM

The regulation of dc bus capacitor voltage involves the estimation of peak amplitude of reference current for harmonic and reactive power compensation [9]. The dc link voltage remains constant if there are no switching losses and no real power absorption from it. The dc link capacitor plays two roles: In steady state it sustains a dc voltage with small ripple, and in transient state it acts as an energy storage element to supply a real power difference between source and load.

However, practically there are switching losses in APF. These losses will increase with increase in the reactive power demand of the load. When the load condition changes the real power balance between source and load will not be constant. Thus in both cases the voltage of the capacitor will change if the real/reactive power demand of the load increase and decreases. Thus the peak value of reference source current will be estimated by surveying this capacitor voltage

using real power balance theory [6]. This approach is aggrandized for the reason that the generation of reference current is done without referring either current harmonics or reactive power of the load. The hardware implementation is so simple and the instantaneous compensation is made using conventional PI algorithm thereby the system reliability is increased. “Fig 2” represents the control process involved in PI algorithm.

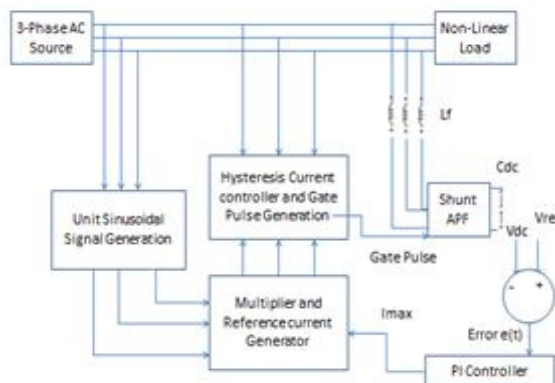


Figure 2. Control Process of PI Algorithm

The actual voltage across dc link capacitor is compared with the reference voltage, error ( $V_{dc} - V_{ref}$ ) is processed through the PI controller and the output of the PI controller is the required peak amplitude of fundamental component of source current. The transfer function is represented as

$$H(s) = K_n + K_I/s \quad (1)$$

The formulae [8] used for finding the parameters of PI controller are

$$K_n = 2\xi\omega_n C, \quad K_l = C\omega_n^2 \quad (2)$$

Where damping factor  $\xi = \sqrt{2}/2$  and  $\omega_n$  is natural frequency and should be fundamental frequency. The peak reference current is estimated for the control of dc link voltage using this controller.

#### IV. FUZZY CONTROL ALGORITHM

In fuzzy logic controller a array of amateur linguistic rules are developed in order to perform the control action over an error. As like conventional PI controller the precise mathematical model for the system is not needed in fuzzy system, because the detailed review over the process is more enough to develop the required rules.

The basic block diagram of fuzzy inference system is shown in “fig 3”. The error E and the change of error CE ( $e(n)-e(n-1)$ ) are the two inputs for fuzzy controller [7]. The numerical values of these inputs are converted into linguistic variables and represented as NB(Negative Big), NM(Negative Medium), NS(Negative Small), ZE(Zero), PS(Positive Small), PM(Positive Medium, PB(Positive Big). The fuzzy rules for controlling the error are erected by expert experience. Table I shows the fuzzy rule base for reference current generation [5].

The process involved in fuzzy inference system is

- **Fuzification Interface-** The process of converting crisp input value to the fuzzy value.

- **Date Base-** Defines the membership functions used in fuzzy rules
- **Rule Base-** Selection of set of fuzzy rules

The actual voltage of dc link capacitor is compared with the reference value and the error signal is processed through fuzzy logic controller and the output of fuzzy controller is the required peak magnitude of source current  $I_{\max}$ .

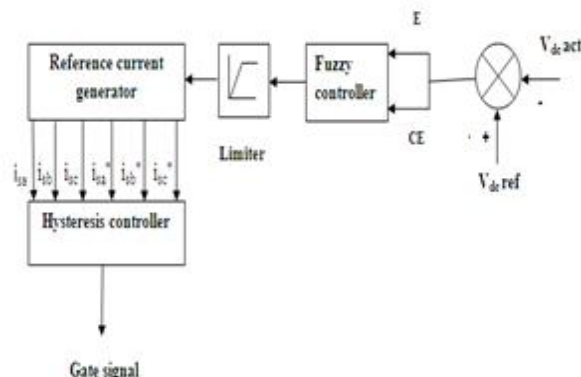


Figure 3 Block diagram of Fuzzy Inference system

TABLE I. FUZZY RULE BASE FOR REFERENCE CURRENT GENERATION

<b>E/CE</b>	<b>NB</b>	<b>NM</b>	<b>NS</b>	<b>Z</b>	<b>PS</b>	<b>PM</b>	<b>PB</b>
<b>NB</b>	NB	NB	NB	NB	NM	NS	Z
<b>NM</b>	NB	NB	NB	NM	NS	Z	PS
<b>NS</b>	NB	NB	NM	NS	Z	PS	PM
<b>Z</b>	NB	NM	NS	Z	PS	PM	PB
<b>PS</b>	NM	NS	Z	PS	PM	PB	PB
<b>PM</b>	NS	Z	PS	PM	PB	PB	PB
<b>PB</b>	Z	PS	PM	PB	PB	PB	PB

## V. SIMULATION RESULTS

The system is designed for 5KVA APF and the system parameters [4] are shown in table III. “Fig.4” & “Fig.5” show the response of the system and harmonic spectrum analysis using conventional PI controller.. “Fig. 6” & “Fig. 7” show the response of the system & harmonic spectrum analysis using fuzzy control algorithm. The results obtained for both the cases are compared in table II.

TABLE. II COMPARISON OF RESULTS OBTAINED

CASE CONSIDERATIONS	KP	KI	SETTLING TIME OF VDC (MS)	THD(%)
Without APF	-	-	-	27.28
With APF (Conventional PI)	0.1414	5	200	1.71
APF with Fuzzy Controller	-	-	60	2.29

TABLE III. SYSTEM PARAMETERS

S.NO	PARAMETER	VALUE
1	Supply voltage (V) and frequency (f)	100 V (peak), 50HZ
2	Source Resistance ( $R_s$ )	0.1 $\Omega$
3	Source Inductance ( $L_s$ )	0.15mH
4	Load Resistance ( $R_L$ )	6.7 $\Omega$
5	Load Inductance ( $L_L$ )	20mH
6	Filter Resistance ( $R_f$ )	0.1 $\Omega$
7	Filter Inductance ( $L_f$ )	0.66mH
8	Filter Capacitance( $C_f$ )	2000 $\mu$ F
9	Reference voltage( $V_{dc}$ )	220V

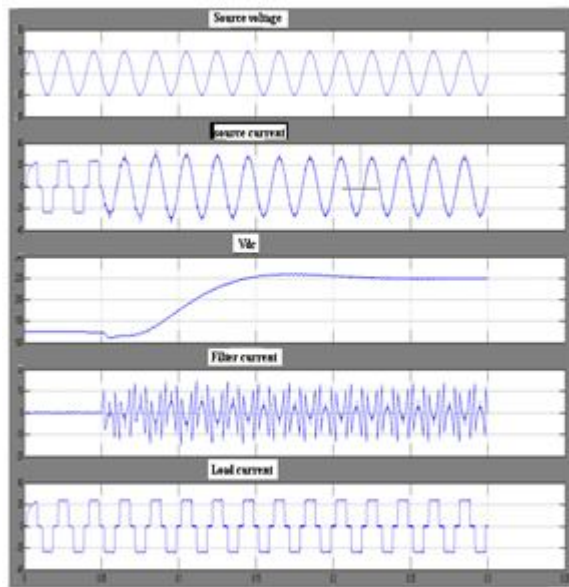


Figure 4. Response of the system after compensation using PI control algorithm

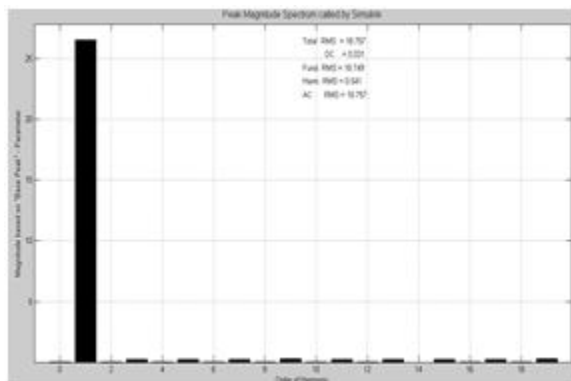


Figure 5. Harmonic analysis of source current after compensation using PI control algorithm

## VI. CONCLUSION

In the present work, shunt APF with PI control algorithm and fuzzy control algorithm is used for eliminating the harmonics present in the load. The typical diode bridge rectifier

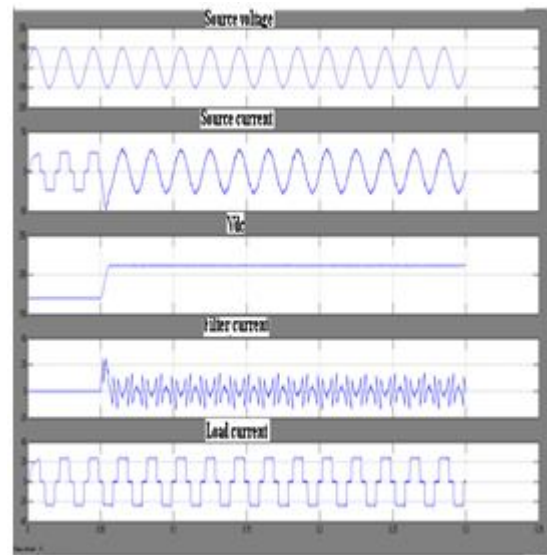


Figure 6. Response of the system after compensation using fuzzy control algorithm

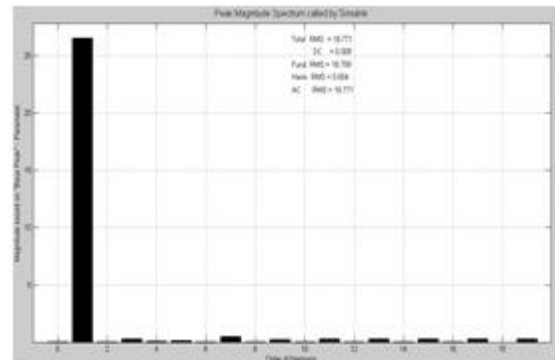


Figure 7. Harmonic analysis of source current after compensation using fuzzy control algorithm

is used as non-linear load and simulation is carried out using MATLAB simulink. The performance of system before and after compensation is validated using both the techniques. Simulation results show the effectiveness of the desired parameters of APF for reactive and harmonic power compensation. Based on the simulation results it can be concluded that the developed fuzzy controlled SAPF is able to reduce the settling time as well as reducing the THD of the source current well below 5% as per the IEEE-519 standard.

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